A COMPARATIVE STUDY OF REMOTE SENSING PARAMETERS IN THE MINERAL BELTS OF BUNDELKHAND

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by
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CERTIFICATE

This is to certify that the present work titled, "A COMPARATIVE STUDY OF REMOTE SENSING PARAMETERS IN THE MINERAL BELTS OF BUNDELKHAND" has been carried out by Shri Mukesh Singhai under my supervision and the same has not been submitted elsewhere for a degree.

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ABSTRACT

There are two important mineral belts in the Bundelkhand region. The quartz reefs of Bundelkhand have achieved economic significance because of their close association with pyrophyllite and diaspore. Towards the southern end of the Bundelkhand massif, this assemblage grades into base metal sulphide deposits in meta-sediments. The standard remote sensing imageries were evaluated as a guide to exploration in this economically potential area. A comparison of Landsat imageries, aerial photographs and topographic sheets was supported by field work at selected places. It is suggested that signatures like (1) Topography and Boundary conditions, (2) Drainage, (3) Vegetation and Tone and (4) Land use can be used as keys for remote sensing of natural resources in this area.

CHAPTER 1

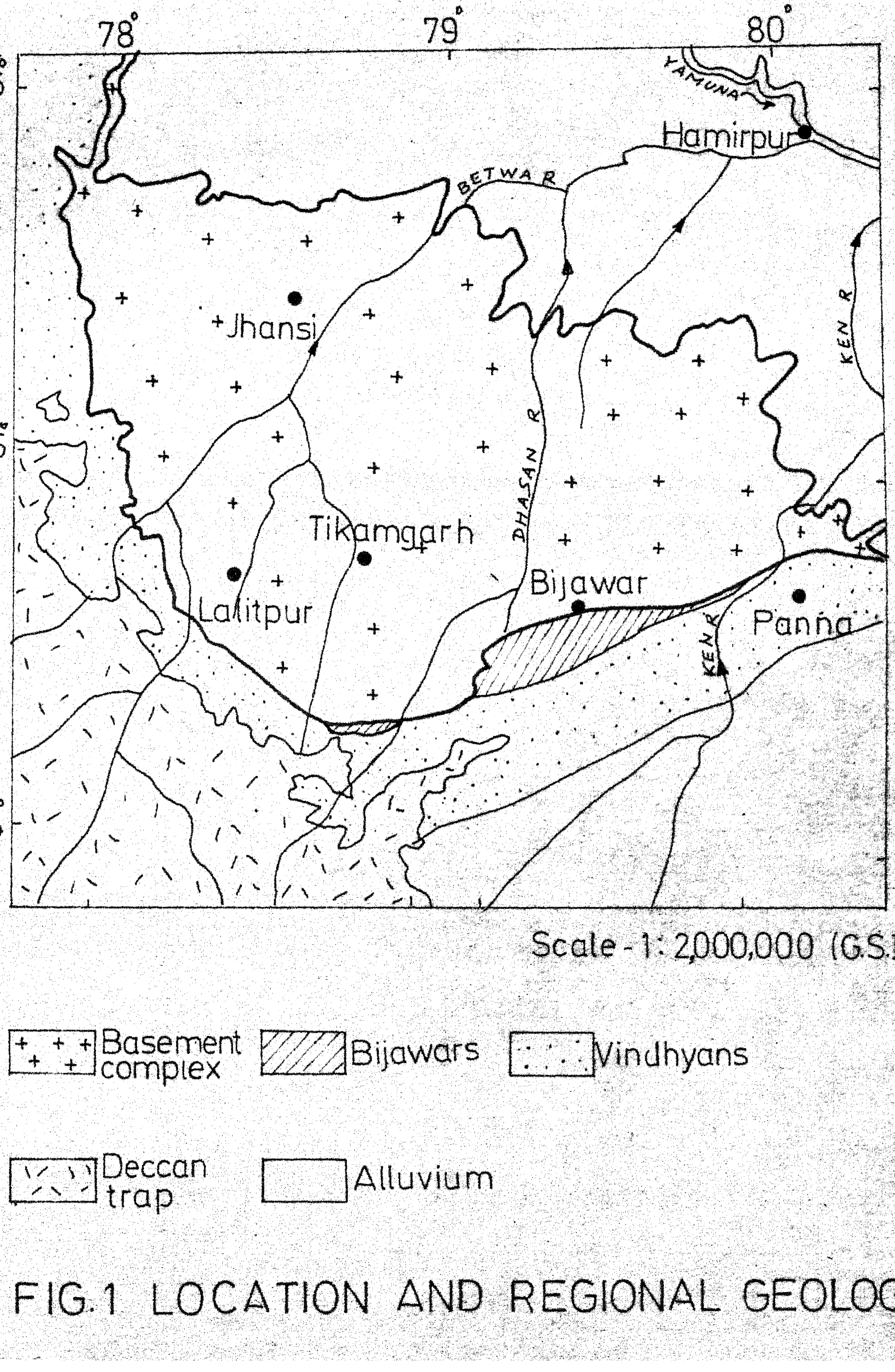
INTRODUCTION

1.1 GEOLOGICAL SETTING:

Bundelkhand is the term applied to the flat undulating country in southern Uttar Pradesh and adjoining Madhya Pradesh. This term, derived from the name of an ancient clan inhabitating this area, has been brought into the geological literature to describe Precambrian basement rocks of granitic affiliation which outcrop in this part of the Indian shield.

The region is bounded by longitudes 77°45' to 80°30' East and latitudes 24°30' to 25°30' North (Fig. 1). It is surrounded by the Gangetic alluvium to the north and by the hilly tracts of Bijawar, Vindhyan and Deccan Traps to the south and southwest. Within the Bundelkhand terrain, linear ridges are formed by quartz reefs trending NE-SW and dolerite dykes trending NW-SE.

Important towns like Jhansi, Lalitpur, Tikamgarh and Bijawar are situated in the Bundelkhand region. The area is therefore, easily accessible by road and railway.



Scale - 1: 2,000,000 (G.S.I. 1962)

FIG. 1 LOCATION AND REGIONAL GEOLOGICAL MAP

The climate of Bundelkhand region is of the tropical monsoonic type. It is dry and cold in the winter with temperature approaching 0°C, and becomes very hot and dry in the summer (+45°C). Occasional showers and storms occur throughout the year, but the bulk of the rain falls between June and October. Average annual rainfall is about 100 cms. Over 90% of the land in the area is cultivated or used for cattle grazing (Bogdanov and Prakash, 1974).

1.2 ECONOMIC MINERAL OCCURRENCES:

The quartz reefs within the Bundelkhand massif are well known for their content of pyrophyllite and diaspore. These scarce raw materials for the refractory industry are at present mined by M/s Eastern Minerals Company of Jhansi. Bundelkhand Granite is used as a building and ornamental stone in the neighbouring areas. The coppersulphide mineralisation near Sonrai and the rock assemblage between Sonrai and Berwar is also considered promising for economic deposits of copper, lead-zinc, nickel and uranium.

1.3 REMOTE SENSING TECHNIQUES:

Remote sensing is survey of earth's surface through instruments which do not come in contact with objects or

features being surveyed. Some common instruments used for Remote sensing are listed below:

1) Electromagnetic Sensors: Aerial cameras for colour photography, Black and white (panchromatic) photography, colour Infra-red photography, Black and white Infra-red photography, Spectrometer, Lasers, Photometers, Spectro-photometers, Scanners and Radiometers, Radar.

2) Geophysical Sensors: Gravimeter, Magnetometer, Seismograph, Electriclog, Thermometer, Currentmeter.

Remote sensing of the earth from space has been defined as a methodology to assist in characterising the quality and condition of natural resources, geographical features and phenomena in the earth's environment by means of observations and measurements from space platforms.

The sensors operate in various parts of the Electromagnetic Radiation Spectrum (Fig.2). Potential sensors are in wave length range 0.01 micron to 1000 microns. However, sensors in current use operate only from 0.4 micron to 1.1 microns (400 to 1100 nanometers). Black and white photography is one of the earliest and most common of remote sensing techniques. The different ranges of Multispectral scanners carried by satellites are:

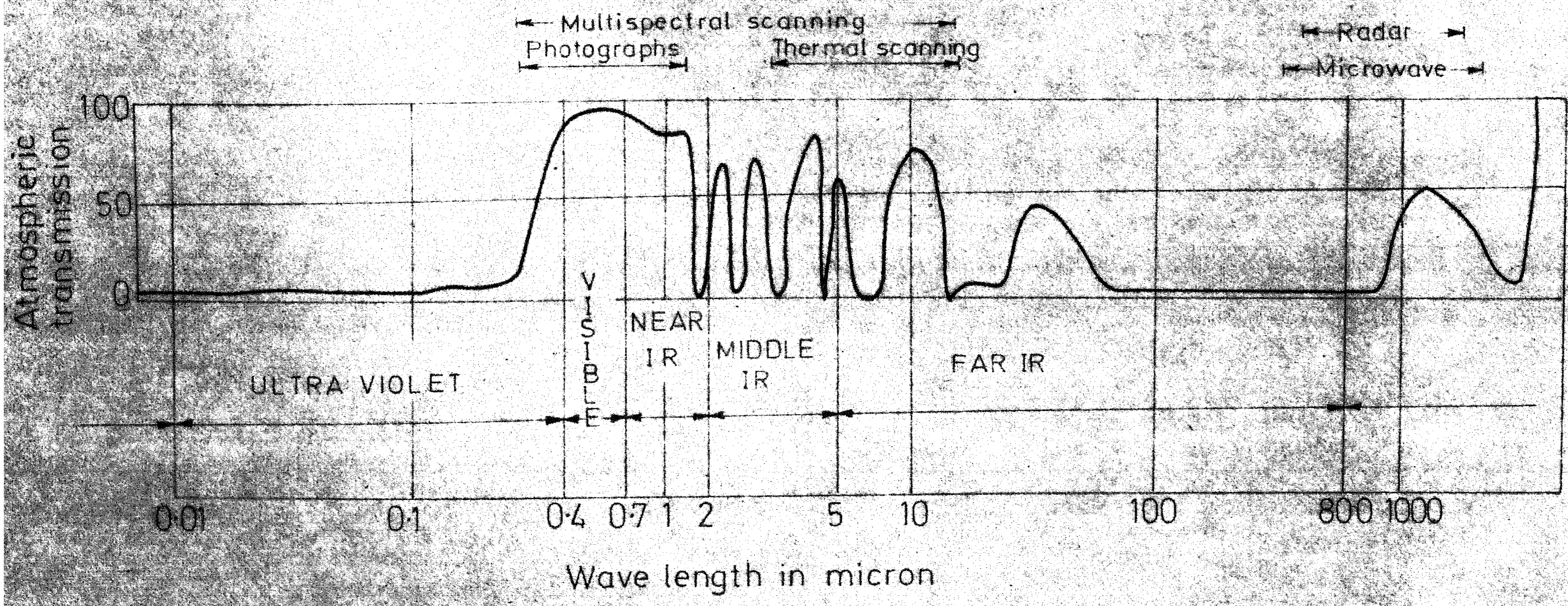


FIG.2 ELECTROMAGNETIC RADIATION SPECTRUM

MSS band 4 - 500 to 600 nm (Green)

MSS band 5 - 600 to 700 nm (Red)

MSS band 6 - 700 to 800 nm (near IR)

MSS band 7 - 800 to 1100 nm(near IR)

The first Earth Resources Technology Satellite (ERTS-1, now renamed as LANDSAT-1) was launched by NASA on July 23, 1972. Its basic mission was:

1) to ascertain which natural resources and environmental data could be best acquired from the use of space-craft,

2) to test data acquisition and methods for interpreting it in such diverse areas as forestry, geology, hydrology, oceanography and ecology,,

3) to determine how outer space remote sensing could serve the commercial, scientific and other agencies.

The second Remote Sensing Satellite (LANDSAT-II) was launched in January 1975. A third one is expected in late 1978.

Only Landsat-1 imageries have been used in this study together with black and white aerial photographs.

1.4 OBJECTIVE OF THE PRESENT WORK:

The Bundelkhand region, as mentioned above, is an area of immense geologic interest. The significance of the structural features in the basement rock in relation to their origin through regional granitisation has been the topic of detailed research. At the same time, this complex rock assemblage happens to be the source material for a variety of economic mineral deposits. The quartz reefs to the north exercise structural control for the localisation of pyrophyllite and diaspore. The Bundelkhand-Bijawar contact to the south is a stratigraphic trap for base metal deposits. This is an area, therefore, where the 'Ground Truth' is reasonably well documented.

It was decided to adopt this region as a 'pilot area' to develop a methodology for regional assessment through available remote sensing imageries. The detailed objective of the present work was:

1) to compare multispectral Landsat imageries, black and white aerial photographs, toposheets and ground photographs to identify 'Signatures' relevent to mineral exploration,

2) to evaluate the utility of individual parameters in different scales,

3) to trace the evolution of the terrain across a wide interval of time as available through the dates of toposheets, aerial photographs, landsat imageries and field traverses,

4) to develop KEYS for photointerpretation and remote sensing from the above multi-disciplinary approach which would be applicable in similar mineralised belts in the country.

CHAPTER 2

PREVIOUS WORK

2.1 REMOTE SENSING:

The earliest use of remote sensing technique was through study of black and white photographs obtained by cameras fitted into an aircraft. Aerial photography for mapping purposes was introduced in India as early as 1924. Photogeology is a well established branch of science. The multipurpose utilisation of airphotos has been amply described in textbooks like the one by Leuder (1959).

Yudhbir et.al. (1975) interpreted aerial photographs of a Siwalik terrain for drainage pattern, control of structure on drainage, ground water conditions, vegetation, land use and engineering characteristics of rocks and soils.

Aerial photographs of the area under discussion have been interpreted by the Directorate of Geology and Mining U.P. (Prakash et.al. 1970) for exploration of pyrophyllite deposits.

Singh et.al. (1977) have found aerial photographs to be of immense help for the inventory of mineral resources in the southern part of Chandrapur district of Maharastra.

Multispectral photography was used for mineral exploration in Australia and Africa by Cole and Jones (1972).

Modern remote sensing for geological projects is largely based on interpretation of Landsat imageries. Jenson (1973) studied Landsat-1 imageries covering Utah and Nevada as an aid in structural geology, mineral exploration and limnological and hydrological aspects.

Schmidt (1973) used Landsat imageries in conjunction with known geology to evaluate one previously known prospect area and to suggest two additional ones in the search for porphyry copper deposits in Pakistani Baluchistan.

The structural lineaments map of Gaspe (Steffenson, 1973) has been used successfully to direct exploration efforts over specific target areas, to interpret geophysical survey data, to support the delineation of trends in the distribution of regional geo-chemical anomalies and to improve the understanding of the tectonic framework of the peninsula.

Interpretation of Landsat imageries has just started in India. Srinivasan and Sreenivas (1977) have prepared a geologic map of Karnataka from MSS band 5 of Landsat-1. Recently, a pair of frames of repetitive imagery of Landsat-1 covering a part of the Godavari valley of Central India was studied by Raju et.al. (1977) employing a conventional mirror stereoscope.

An attempt was made by Ramesam and Achutha Rao (1977) to estimate the total depression storage in a part of the Vedavati catchment (Krishna Basin) using MSS. The study also helped in identifying lithological boundaries and areas of likely groundwater potential.

Some preliminary results of this thesis project was presented by Singhai and Raymahashay (1977), who brought out the correlation between Ground Truth and Signatures, in parts of Bundelkhand.

2.2 REGIONAL GEOLOGY:

A comprehensive description of Bundelkhand region is available in the manual by Pascoe (1965). Our present knowledge of the various rock formations of this area is due to the pioneering work of R.C. Misra, A.G. Jhingran and

M.N. Saxena as reviewed by Prakash et.al. (1970). The so-called Bundelkhand "granite" is a typical regional precambrian granite. Stratigraphically equivalent to the basement complex in Rajasthan, this granite massif has two distinct petrographic and tectonic blocks. These are the "Bundelkhand Granite" proper towards the north and the "Mehroni Schist Belt" towards the south (Bogdanov et.al. 1974). The northern block is a coarse grained, porphyritic, pink granite. The southern block is a zone of metasedimentary rocks cut by granitic and mafic intrusives (Table 1). This southern block has a fault contact with the Bijawar group which in turn is unconformably overlain by the Vindhyans. The Deccan Basalts coverup the southern most margin of the area. (Fig. 1).

According to Pascoe (1965) the quartz ridges are confined to the granitic tract and contain impure serpentine and steatite. R.C. Misra in 1944 correctly identified these to be quartz-pyrophyllite-diaspore reefs (Prakash et.al. 1970). Although the northern block is the characteristic environment for this assemblage, pyrophyllite mineralisation has also been reported near Berwar (24° 18' 30" N, 78° 54' E) at the Basement-Bijawar boundary (Prakash et.al. 1970). Rao et.al. (1971) have summarised thermal properties of pyrophyllite and diaspore from Jhansi area.

TABLE 1

STRATIGRAPHIC SEQUENCE OF BUNDELKHAND REGION

Adopted from Bogdanov and Prakash (1974).

Recent Alluvium	
Deccan Trap lavas	- Basalt
Vindhyans	- Shale, Conglomerate, Sandstone with Laterite Cap.
Bijawars	- 4. Pillow Lavas (Kurrat) 3. Iron formation (Solda) 2. Chloritic shale, sandstone, sulphide bearing (Dhori Sagar) 1. Basal carbonate, sandstone, shale, graphitic with copper ore (Sonrai).
Basement Complex	- 2. Porphyritic granite, N. Block (Bundelkhand Granite) 1. Metasediments with ultramafic to acid intrusives, S. Block (Mehroni Group)

The contact zone with the Bijawar, on the other hand, has now been recognised as representative of epigenetic base metal sulphide mineralisation (Bogdanov et.al., 1974). The copper mineralisation near Sonrai (24° 19' N, 78° 46' E) has been described by Singh and Goyal (1972). The entire area is also considered promising for economic deposits of lead-zinc, nickel and uranium.

Prakash et.al. (1970) propose the following sequence of events for the origin of Bundelkhand rocks :

1. Metamorphism of Mehroni - Mouranipur sediments (which are equivalent to Dharwars).
2. Formation of an acidic magma which granitised the meta-sediments.
3. Differentiation of the magma leading to injection of quartz-rich fluids, fracturing and localisation of pyrophyllite as a late-stage hydrothermal mineral.
4. Intrusion of basic dykes which were feeders for the eruption of Deccan basalts.

CHAPTER 3

METHOD OF WORK

The stated objective of this study was to develop suitable keys for remote sensing of a mineralised terrain. The Bundelkhand region was adopted as a pilot area for evolving a methodology for this purpose. Special efforts were made to use readily available aerial photographs, landsat imageries and toposheets so that this technique can be applied to other terrains also. After initial literature survey, the work was carried out at four levels :

1. Through multispectral landsat satellite imageries (NASA-ERTS-1148-04413) of approximately 1 inch = 16 miles scale. The transparencies were studied on a light table and overlays were prepared on a tracing paper (Figure-8).

2. Through stereopairs of black and white aerial photographs (518A/195-199 to 121 ; 518A/213B-8, 9, 10; 214-1,2 series) of approximately 1 inch = 1 mile scale.

The first series covers the Bhagwan area east of Tikamgarh and represents a typical Bundelkhand granite

(North Block) terrain. The second series covers the Basement-Bijawar contact between Sonrai and Berwar. This series is also declassified for use in educational institutions. Appropriate photogeologic maps (Figure 4 & 6) were prepared after observation through a stereoscope.

3. Through Survey of India quarter inch toposheet no. 54 P and 54 L and one inch toposheet no. 54 P/2 and 54 L/15 . These were useful in recognizing villages, rivers and other cultural features on the landsat and aerial photographs.

4. Through limited field work at the mining camps at and around Sonrai, where a few drill hole samples were observed. Rock samples collected during earlier field work by Dr. B.C. Raymahashay in the Tikamgarh area were also studied in hand specimen and thin section for detailed mineralogic description.

This method enabled the study of the terrain not only at various scales but also across a wide interval of time. For example, the toposheet 54 L/15 (Third Edition, 1971) is based on an original survey conducted in 1906-07. Similarly, toposheet 54 P/2 (Second Edition, 1954) is based

on the original survey done in 1926-27. The aerial photographs are dated November 9,1966 and the date of the satellite imageries is December 18, 1972. Field work was carried out in 1977.

CHAPTER 4

RESULTS AND DISCUSSION

The remote sensing imageries and other supporting materials available for the Bundelkhand region were interpreted in terms of the standard five KEYS of photo-interpretation (Leuder, 1959). These are (1) Topography and Boundary Conditions, (2) Drainage, (3) Vegetation, (4) Tone and (5) Land use. The results are summarised below:

4.1 INTERPRETATION OF TOPOSHEET:

Average height of the area is 1100-1150 feet above MSL with the ridges rising 50 to 300 feet above plains. The quartz reefs appear as concentration of contour lines elongated in a general NE-SW direction. Minor strike-slip faults in quartz ridges are clear from change in orientation of the contour lines (Fig. 3). The contour pattern near Dhori Sagar shows a probable fold. Vindhyan scarps are clear from contour lines towards south elangated in ENE-WSW direction.

The drainage pattern of the area is dendritic in general and rectangular at a few places. It is clear from the toposheet that the strike displacement of quartz reefs is

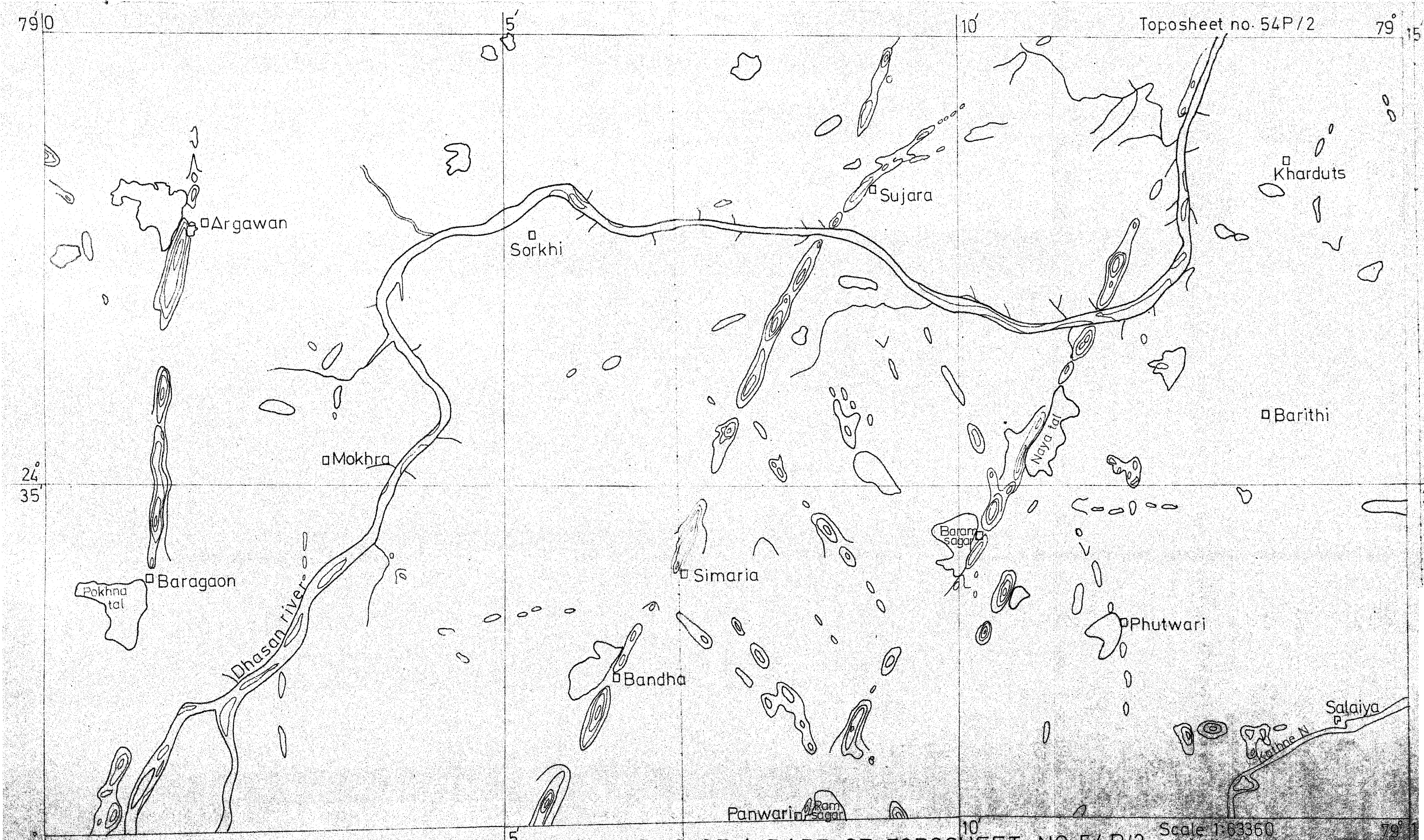


FIG.3 TRACING OF A PART OF TOPOSHEET NO. 54P/2

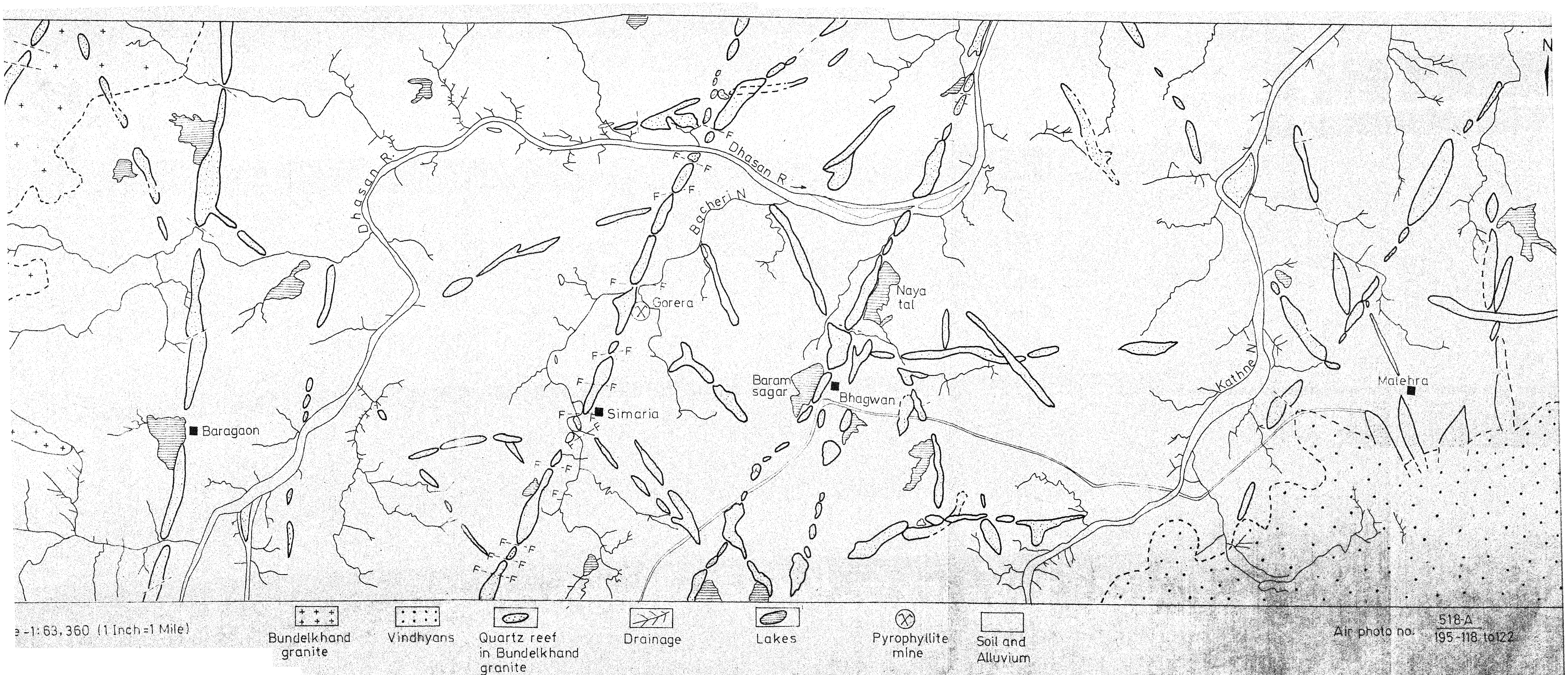


FIG.4 PHOTOGEOLOGICAL MAP OF PYROPHYLLITE-QUARTZ REEFS

responsible for a rectangular drainage pattern in the region east of Tikamgarh. The region is covered by dense forests and dotted by a number of ponds and storage tanks.

4.2 INTERPRETATION OF AERIAL PHOTOGRAPHS:

4.2.1 Boundary conditions:

The quartz reefs are easily identified on aerial photographs because they are ridge formers. They have faulted ends and sharp boundaries with the sorrounding granite complex (Fig. 4).

A statistical analysis of the strike directions of quartz reefs as obtained from the aerial photographs revealed that major orientations are in the N 20°-30°(NE) and N 330°-340° (NNW) directions. The data are presented in Table 2 and plotted in a rosette in Fig. 5. Prakash et.al. (1970) gave a genetic classification of fracture trends in Bundelkhand. According to these authors, a conjugate pair of shear fractures are represented by the N20° and N95° sets which developed due to maximum horizontal stress acting from ENE. On the other hand, the N 350°-35° and N95°-100° sets represent tension fractures that formed under a right handed shear movement on the first set. It was also found that the best control on

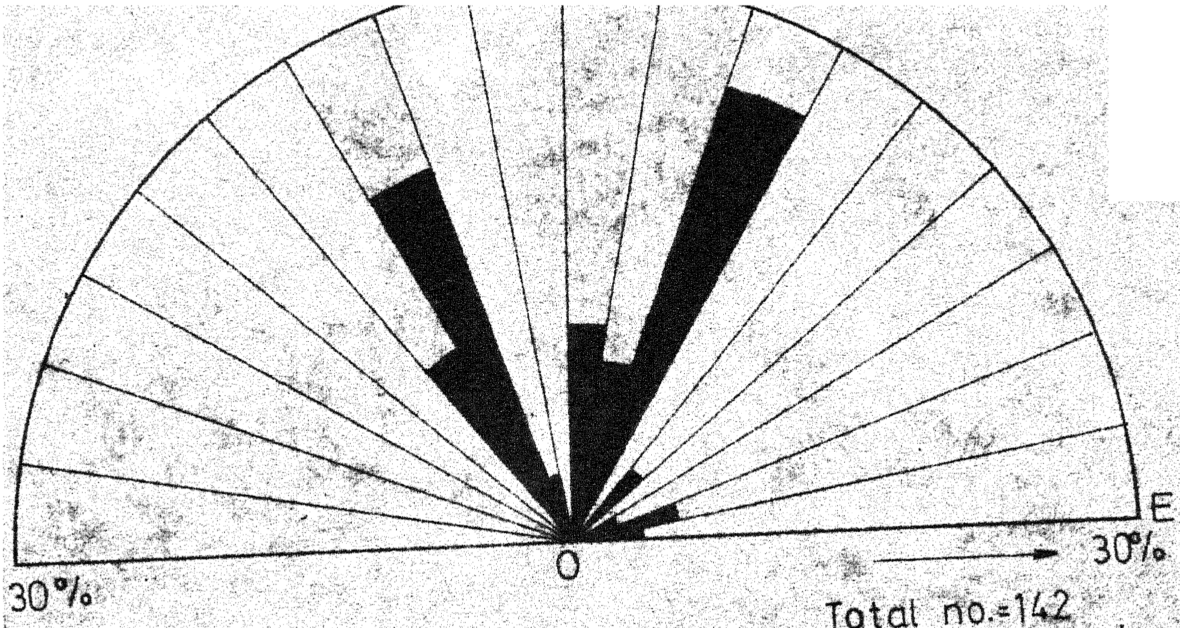


FIG.5 ROSE DIAGRAM SHOWING STRIKE DIRECTIONS OF QUARTZ REEFS

TABLE 2

STRIKE DIRECTIONS OF THE QUARTZ REEFS AS OBSERVED ON AIR PHOTO(Fig.4).

Strike Direction	Number of Lineaments	Percent of Total Lineaments
0 - 10°	16	11.3
11 - 20°	14	9.8
21 - 30°	36	25.3
31 - 40°	-	-
41 - 50°	7	4.9
51 - 60°	-	-
61 - 70°	3	2.1
71 - 80°	8	5.6
81 - 90°	5	3.5
310 - 319°	1	0.7
320 - 329°	17	11.9
330 - 339°	30	21.1
340 - 349°	5	3.5
350 - 360°	-	-

pyrophyllite mineralisation are intersections of quartz reefs filling the shear and tension fractures. These studies clearly bring out the importance of a systematic analysis of lineament patterns in aerial photograph for structural geology and mineral exploration.

Aerial photographs of the southern part of Bundelkhand region also show the E-W striking, steeply south dipping Bijawar rocks (Fig.6). These ridges are cut by strike-slip faults. The fold pattern of a syncline plunging towards WSW can be deciphered near Dhorisagar lake. The distinction between subdivisions of Bijawars is not very clear. Contact of Bijawars with Deccan Traps and vindhyans can be traced by tonal difference.

4.2.2 Drainage:

The intricacies of drainage are best observed in the aerial photographs. A rectangular drainage pattern is clear which is due to the strike displacement of quartz reefs (Fig.4, Pl.2). Although the pattern is rectangular in higher elevations, it tends to be dendritic in low lands. The Basement-Bijawar boundary acts as a prominent drainage divide between the Bandai and Rohini systems (Fig. 6). Uplands, in the basement, also act as local drainage divides. The course of the Bandai river is obviously

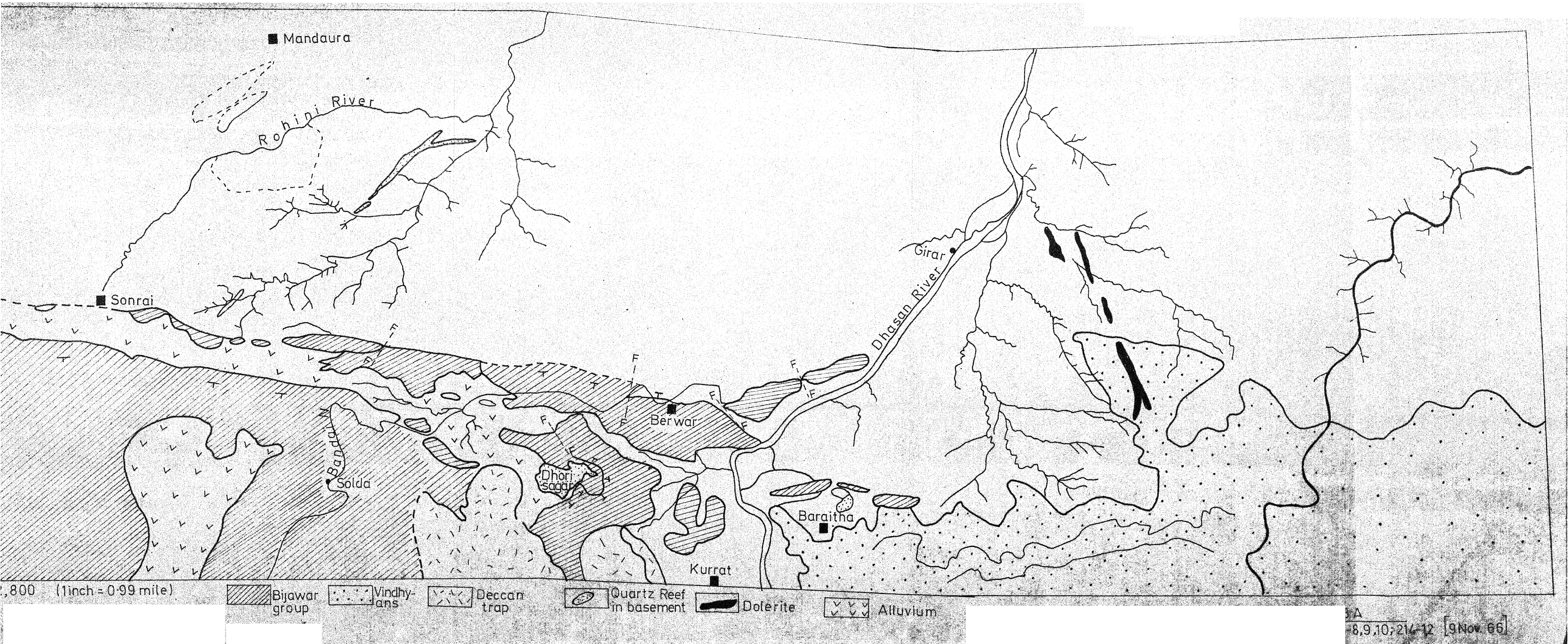


FIG. 6 PHOTOGEOLOGICAL MAP OF BASEMENT-BIJAWAR CONTACT

PLATE-2

View towards northeast of pyrophyllite-diaspore-quartz reef near village Gorera(Sarkana Mine). Bacheri Nala has an eastward bend across the reef as it follows a strike-slip fault (compare Fig.4)

Photo: Dr. B.C. Raymahashay
6.3.75

PLATE-3

Typical V_in quartz at foot hill of the quartz reef near Gorera

Photo:Dr.B.C.Raymahashay

PLATE-4

Pyrophyllite-diaspore mine near village Khera (Gora Pahar). Note strongly foliated and jointed nature of the rocks.

Photo: Dr.B.C.Raymahashay
7.3.75

fault and joint controlled.

A quantitative analysis of the drainage basin of a small tributary of the Rohini system was carried out to compare the results from toposheet and airphoto. Stream order and stream number were found to have a linear relationship according to Horton's Law. Two other parameters were estimated namely (1) Bifurcation Ratio (Rb) = N_u/N_{u+1} where N_u is the number of streams of a given order and N_{u+1} is the number for the next higher order, (2) Drainage-Density (D) $= \Sigma L/A$ where ΣL is the total length of streams within the basin and A is the area of the basin. Basin A (Fig.7) as obtained from toposheet 54 L/15 gives a mean Rb = 2.96 and D = 3.36 miles/sq.mile (Table 3). Observation of the corresponding airphoto (Fig. 6) indicated that this basin cuts across the Granitic Basement-Bijawar boundary. Basin B (Fig. 7) is thus selected to cover the granitic terrain only. The values now change to mean Rb = 3.87 and D = 2.65 miles/sq.miles. Either set of D values is quite different of the average 9 miles/sq.miles obtained by Belcher and Majtenyi (1967) from granitic rocks of N. Carolina. Although drainage density is sensitive to rock type, climatic condition etc., it is suggested that a major factor in the present case is the extensive weathering, soil formation and cultivation over the Bundelkhand

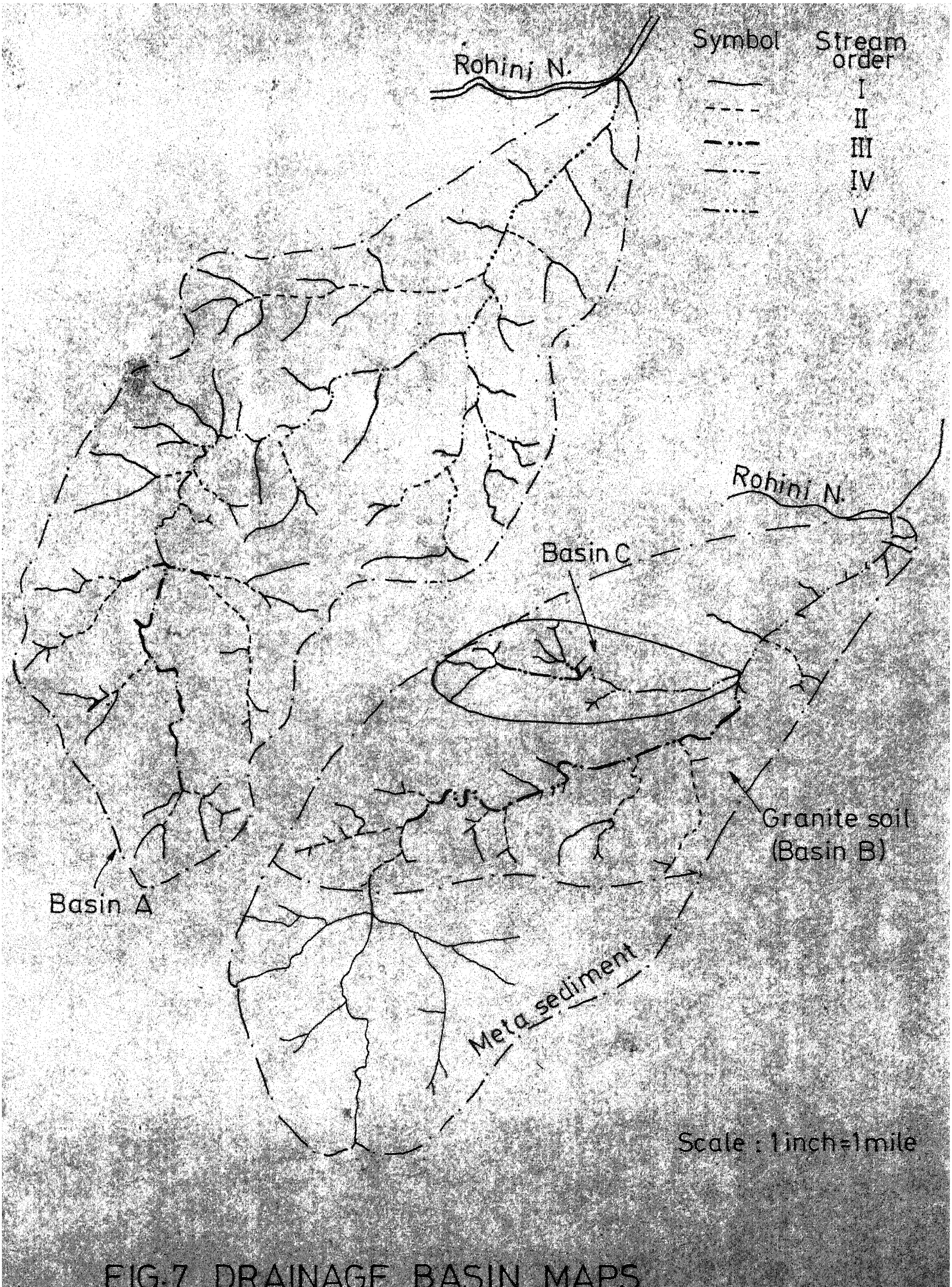


FIG.7 DRAINAGE BASIN MAPS

TABLE 3

DRAINAGE BASIN ANALYSIS OF A SMALL BASIN IN THE ROHINI SYSTEM

Stream Order	BASIN A from Toposheet		BASIN B From Airphoto		BASIN C from Airphoto	
	No. of Streams	Bifurcation Raio (Rb)	No. of Streams	Bifurcation Ratio (Rb)	No. of Streams	Bifurcation Ratio (Rb)
I	68		56		14	
		3.57		4.30		2.80
II	19		13		5	
		3.80		4.33		2.50
III	5		3		2	
		2.50		3.00		2.00
IV	2		1		1	
		2.00		-		-
V	1		-		-	
	Total-95	Mean-2.96	Total-73	Mean-3.87	Total-22	Mean-2.43
Drainage Density -	3.36 miles/sq.miles		2.65 miles/sq.mls.		4.28 miles/sq.mls.	

granite. This suggestion is further supported when one considers basin C which contains upland areas with low hillocks and less cultivated lands. The value of D increases to 4.28 miles/sq.miles when the weightage of hard rocks in the first order gullies is increased. This comparative study (Table 3) , therefore, emphasizes the importance of distinguishing hard rock from soil cover for drainage basin analysis. The values of drainage density calculated here are representative of the porous and permeable granitic soil rather than the bed rock.

4.2.3 Tone:

The Deccan Trap in the southern part have darkest-tone, followed by the Vindhyans and the Bijawars in the grey tone scale. The light tone of the basement indicates extensive soil cover which is confirmed by the frequency of chequered tonal pattern of farmlands. The NW-SE trending, dark toned lineaments observed on the right bank of Dhasan River NE of Baraitha (Fig. 6) are tentatively correlated with dolerite dykes. The lakes and ponds have dark tone with clear demarcation of vegetation along banks.

4.2.4 Vegetation and land use:

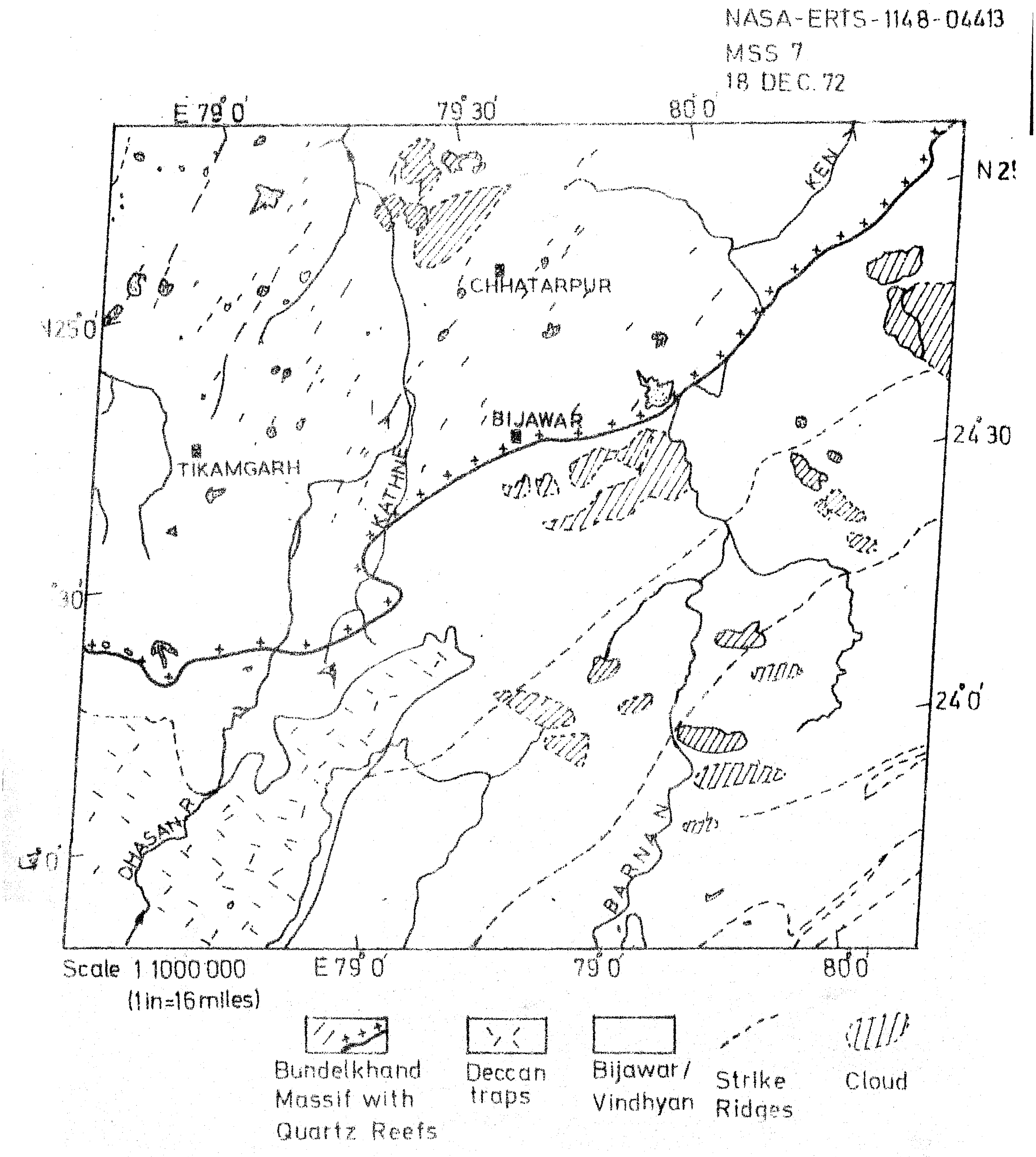
Occurrence of innumerable ponds and storage

land use feature of the Bundelkhand region. Most of the granitic terrain is basically an agricultural area. Cultural features like roads and foot tracks can be deciphered near important villages. The region south of the basement boundary is rugged and densely forested. Low shrub-type of vegetation was observed along gullies and foot hills. However, the scale of photographs (1:62,800) is too small for any further details.

4.3 INTERPRETATION OF LANDSAT-1 IMAGERIES:

The southern boundary of the basement complex stands out as an arcuate line in the landsat imagery both in visible and IR ranges. Even at the small scale of landsat, the quartz reefs appear as distinct lineaments with local bifurcations (Plate-1, Fig. 8). However, the density of quartz reef lineaments diminishes noticeably as the southern boundary of the basement is approached. This supports the prevailing view that the southern part of the Bundelkhand massif represents a tectonic setup different from the northern part (Bogdanov et.al.1974). The boundary between Granite and Bijawar is clear in band 4 and 5 . The imageries do not show any distinction between the subdivisions of Bijawars. Deccan Trap could be marked in band 7. The contact of Bijawars with Deccan Traps and

PLATE 1: Positive Print of MSS Band 7 transparency No. NASA-ERTS-E-1148-04413-7, dated 18.12.72.
Note that grey tone in this print is reversed from the original tranparency.


NASA-ERTS-1148-04413
MSS 7
18 DEC. 72
E 79°0'
79°30'
80°0'
N25
N25°0'
24°30'
30'
24°0'
KEN
CHHATARPUR
BIJAWAR
TIKAMGARH
KATHNE
DHASAN R.
BARNA N.
Scale 1:1000000
(1in=16miles)
E 79°0'
79°0'
80°0'
Bundelkhand Massif with Quartz Reefs
Deccan traps
Bijawar / Vindhyan
Strike Ridges
Cloud

Vindhyans is vague.

The major drainage lines of the Dhasan and the Ken rivers show up clearly with their major tributaries like Kathne, Siamri, Barna etc. But the minor streams and tributaries are not visible. Bifurcations, bends in rivers and sand bars could be seen. A number of lakes and ponds are observed as spots on these imageries.

The Bundelkhand-granite complex has a light tone in Landsat, heavily mottled because of the characteristic land use pattern. Quartz reefs appear as much lighter streaks in this matrix. The Deccan Traps have the darkest tone in the southern parts, followed by the Vindhyans and the Bijawars. The rivers have a greyish-white tone in MSS band 4, 5 and dark in band 6, 7. The lakes and ponds have dark tone. The quartz reefs with sparsely vegetated slopes have clear signature in the imageries.

The most noticeable feature of the Bundelkhand tract is the occurrence of innumerable ponds and storage tanks dotting the terrain.

4.4 PETROGRAPHIC INTERPRETATION OF ROCK SAMPLES:

Field samples of Granite, Vein Quartz, Quartz-pyrophyllite rock and Dolerite were observed in hand specimen.

Granite and Dolerite were also observed in thin section in order to ascertain the effect of mineralogy, if any, on remote sensing parameters of these rocks.

Bundelkhand Granite is a pink coloured, medium grained rock having felspar, quartz, hornblende and mica minerals. This mineralogy gives a general light tone. At the prevailing climatic conditions, these minerals weather easily. The granitic area, therefore, supports a thick laterite soil cover which again appears with a light and mottled tone.

Vein quartz is white to buff coloured, hard, jointed with geode growth of crystals on joint planes. This texture supports joint controlled vertical slopes at the top of the quartz reefs. These slopes are thus devoid of soil cover and vegetation. This contributes to their light toned streak-like appearances in air photos and Landsat.

Pyrophyllite occurs within the quartz reefs in a complete range from pyrophyllite-quartz rock to pure pyrophyllite. Many of the mineralised veins have a core of diaspore. The bulk assemblage of quartz, pyrophyllite and diaspore gives a light coloured, foliated or jointed rock which has characteristic signatures in remote sensing imageries as discussed above.

Dolerite is greyish-black in colour, medium to fine grained having hornblende, plagioclase, biotite and other mafic minerals in an ophitic texture. It appears as dark lineaments on airphotos.

4.5 APPLICATION TO MINERAL EXPLORATION:

There are two economically important mineral assemblages in the region:

1) Pyrophyllite-diaspore within quartz-reefs in the northern and central part of Bundelkhand massif, which is believed to be genetically related to regional granitisation. It has been observed that mineralisation is most extensive where two quartz-reefs intersect (Prakash et.al. 1970). It would thus appear that the topography and boundary conditions of the quartz reefs are the best prospecting guides for pyrophyllite-diaspore deposits in Bundelkhand. Drainage pattern gives additional clues to the structural modifications of the reefs. These are the clearest signatures in the remote sensing imageries of this area.

2) The metallic ore deposits towards the south occur in the meta-sedimentary environment where quartz reefs are rare to absent. There is a clear cut stratigraphic control for these deposits. The prospecting guides are: (i) a region free of quartz reefs and regional granite outcrops, and

(ii) fault contact between basement and younger meta-sediments. Both these features can be recognised from remote sensing imageries. The landsat imageries in particular, would serve to scan wide areas with respect to presence or absence of lineaments typical of quartz reefs and faulted ridges.

This technique would be a useful addition to conventional geological, geophysical and geochemical methods for evaluation of natural resources.

CHAPTER 5

CONCLUDING REMARKS

The chief objective of this work was to assess the available remote sensing imageries over parts of Bundelkhand region in terms of applicability to mineral exploration. The method of work consisted on recognizing the five fundamental photo interpretation keys of Boundary, Drainage, Vegetation, Tone and Land use separately in Landsat and black and white aerial photographs. The results were compared with supporting information from toposheets and field traverses. The major conclusions are summarised in Table-4.

It is recognised that there is no substitute for field work in actual development of a mineral prospect into a working mine. On the other hand, Remote Sensing is the technique to adopt in the initial reconnaissance stage when the emphasis is on scanning a wide area and picking up the most promising locations on a priority basis. In the Bundelkhand region, the well known pyrophyllite-diaspore quartz reefs in the northern tectonic block have a strong structural control on ore localisation. The topography and

boundary conditions of the reefs together with their structurally controlled drainage pattern give the clearest signatures in remote sensing imageries. It should be an easy task to identify the areas of reef intersections from the imageries before launching a field exploration programme.

In contrast, the control on base metal deposits in the southern tectonic block is dominantly stratigraphic. In fact, an area free of quartz reef lineaments and regional granites should act as a suitable prospecting guide together with drainage indications for the faulted boundary between Basement and overlying meta-sediments. Once again, the suitability of remote sensing imageries for regional scanning is obvious. It is also clear that the advantage of covering very large areas in single frames of Landsat is partly counteracted by the better resolution in the larger scale of aerial photographs.

The aerial photographs are better suited, for example, for drainage basin analysis as compared to Landsat. A quantitative analysis of a small basin in the Rohini System indicated that the regional drainage pattern in the Bundelkhand granite tract is controlled by the porous soil cover rather than the bed rock.

Although this method of work made it possible to evaluate the terrain over a wide time interval from 1906 to 1977, the lack of variation in landforms was remarkable. As figures - 3,4,6,7 and plate-1 show, river courses and associated geomorphology have remained practically unaltered. Possibly, the only change noticeable is in the land use pattern. For example, the size and shape of the ponds and storage tanks show slight modifications. In most cases, the land sorrounding the major lakes like Dhori Sagar, Baram Sagar seem to have been reclaimed for cultivation. Thus the dimensions of the lakes show a decrease from toposheet to airphoto. There have been other minor changes in cultural features like roads near important villages.

It is suggested that this methodology should be tried out in other mineralised belts in the country and the relative importance of the keys developed be evaluated. At this stage, Remote Sensing appears to be a useful addition to the conventional techniques of geological, geophysical and geochemical mapping for mineral exploration.

TABLE 4.

REMOTE SENSING PARAMETERS IN THE BUNDELKHAND REGION

		Landsat	Airphoto
1.	Topography and Boundary	Basement-Bijawar boundary clear. Quartz Reefs as lineaments, diminish towards south.	Quartz reefs, Bijawar ridges, strike offsets, plunging folds. Intersection of quartz reefs potential for ore localisation.
2.	Drainage	Major rivers clear Small tributaries missing. Rectangular pattern controlled by offset of quartz reefs.	Rectangular and dendritic drainage pattern, structural control, drainage divides.
3.	Vegetation and Tone	Deccan traps, Vindhyans darkest, Basement lightest in tone.	Farmland and hilly forested tracts. Lakes and swamps.
4.	Land Use	Tanks and ponds characteristic of basement complex.	Tanks, agricultural land, road network.

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